YEAR
1894

FISKE RANGE-FINDER

AND

RANGE-INDICATOR.

1894

Presented to—

Messrs Warner & Swasey

Cleveland, Ohio

With compliments of—

Bureau of Ordnance,

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INSTRUCTIONS

FOR THE

Installation, Use and Care

OF THE

FISKE RANGE-FINDER

AND

RANGE-INDICATOR.

Published by Authority of the Bureau of
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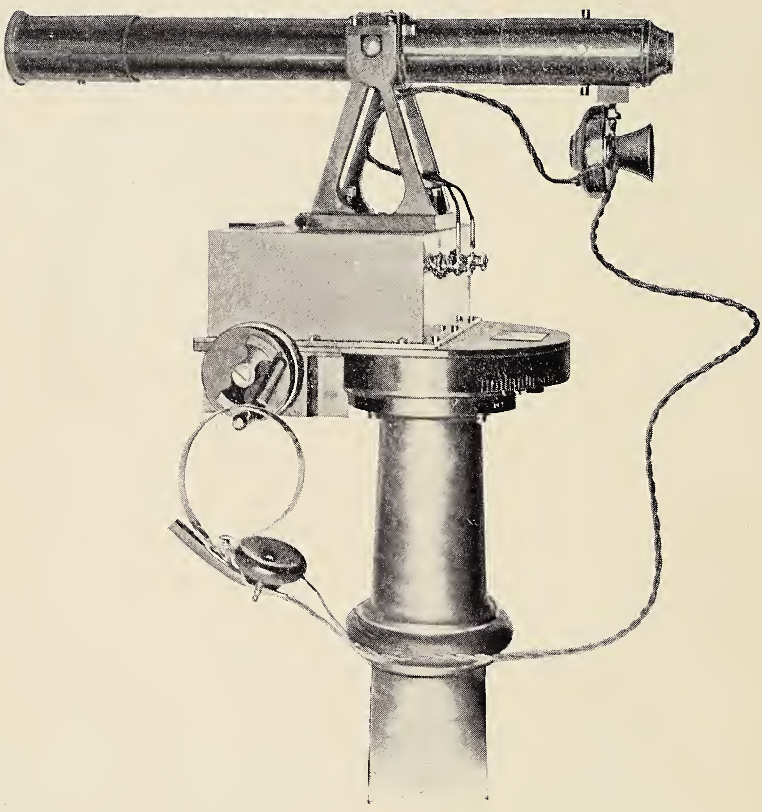


GENERAL PRINCIPLES.

Fig. 1 is a plan view of one of the observing instruments of the range-finder ; Fig. 2 is a vertical section, and Figs. 3 to 7, inclusive, represent details of the mechanism. Before examining these, it may be well to consider the general principles on which the action of the system depends.

Let Fig. 9 represent a Wheatstone bridge connected in the usual way, as indicated. By the well-known theory of the Wheatstone bridge, the needle of the galvanometer g will not move, no matter how strong the current of the battery, if the resistances of the opposite arms of the bridge multiplied together are equal. This is expressed, in electrical parlance, by saying that "the bridge is in balance if $ac = bd$."

Now, if a, b, c and d are all equal, and if the battery contacts e and f are moved from the positions shown, up over equal resistances, which may be expressed by r, the bridge will still be in balance, because the resistances of the opposite arms multiplied together will still be equal. To show this, let Fig. 10 represent the condition of affairs after the contacts have each been moved up over a resistance r.

Evidently $(a - r)\ (c + r) = (b + r)\ (d - r)$, because, since a, b, c and d are equal, this may be written $(a - r)\ (a + r) = (a + r)\ (a - r)$, which is self-evident.

Let Fig. 8 represent the arms a and b bent into the form of an arc h^1, while c and d are bent into the form of an arc h, both of these arcs being wires of conducting material. Let telescopes, pivoted at A and B, be fitted with the contacts e and f. Now, if the extremities of the semi-circular arcs are in the same line, the contacts carried by the telescopes will press on the middle parts of their respective arcs, and the galvanometer will, therefore, not deflect, whenever the telescopes are parallel and at right angles to the base line, because, as said above, $ac = bd$. But when the telescopes are parallel they are directed at some point in space infinitely distant; that is, the distance of the object towards which the telescopes are directed is infinite. Now, let the telescope be directed at some point T not infinitely distant. The telescopes will converge and the angle of convergence is clearly the angle ATB, or the angle CAE, which is measured by the arc CE. In other words, the degree of convergence is measured by the difference in the positions of the contacts of the

telescopes on their respective arcs. But, if the bridge was in balance when both contacts were at the middle points, it will clearly not be in balance when one is at the middle point of its arc and the other at C ; and the amount by which it is out of balance will clearly vary with this difference of positions. That is, the greater the amount of convergence of the telescopes, the greater the deflection of the galvanometer ; so that the deflection of the galvanometer varies with the angle ATB. By trigonometry,

$$AT = \frac{AB}{\text{sine } ATB} \times \text{sine } ABT. \qquad (1)$$

From this formula it is plain that, if ABT be a right angle, the distance AT varies inversely with the sine ATB ; and it is, therefore, plain that, if the electro-motive force of the battery remains constant, the deflections of the galvanometer vary inversely with the distance ; so that, if we know the length of base, we may graduate the galvanometer directly in units of distance, remembering that with such small angles as ATB always is in range-finding, the sine of the angle is practically the same as the arc.

But suppose that ABT is not a right angle. Suppose, first, that the target pointed at by the telescopes is infinitely distant, but in a direction inclined to the base. The contacts carried by the telescopes will not now press on the middle points of their arcs, but on points equally removed from the middle points. This is evidently the condition shown in Fig. 10, where the contacts have been moved away from the middle points over equal resistances. The galvanometer will not deflect, but will remain at its position of rest, which position on the galvanometer may be marked "infinity."

Let one contact be now moved from its position so that the telescopes converge and point at some object not infinitely distant. The galvanometer will deflect. In order to indicate the true distance of the object, the galvanometer must now deflect, not in proportion to sine ATB, but in proportion to sine ATB ÷ sine ABT. In other words, it must deflect more for an angle of convergence ATB than if ABT were a right angle ; and the smaller ABT is, the more the needle must deflect.

In the range-finder this increased movement of the needle is obtained by taking advantage of the curious fact that the current in the Wheatstone bridge increases as the contact points are moved away from the middle points. This is because the resistance of the bridge is less ; so that, if the electro-motive force of the battery is constant, the current increases proportionally as the resistance decreases.

To show this, it is simply necessary to point out that, by the "Law of Derived Circuits," the resistance of the bridge in Fig. 9 is

$$\frac{(a+d)\,(b+c)}{a+b+c+d} = \frac{(2a)\,(2a)}{4a} = \frac{4a^2}{4a}, \tag{2}$$

while in Fig. 10, it is

$$\frac{(\,(a-r)+(d-r)\,)\,(\,(b+r)+(c+r)\,)}{a+b+c+d} = \frac{(2a-2r)\,(2a+2r)}{4a} = \frac{4a^2-4r^2}{4a}, \tag{3}$$

which is evidently less than $\frac{4a^2}{4a}$.

If the current is stronger in the "bridge" (that is, in the circuit), it follows that the galvanometer will move further for any movement of either telescope away from parallelism with the other telescope. It remains then to so arrange the circuit that the increase of current, when both telescopes are at, say, 45°, shall be inversely proportional to sine 45°; that is, that the current shall be $\frac{1}{.707}$ times as strong in the circuit when they are at 45° as when they are at 90°, .707 being the sine of 45°. Neglecting, for a moment, the resistance of the battery and the battery wires, we see that this can easily be done by simply making the length of the arcs, not 90° long each side of the central point, but of such length that the resistance of the "bridge," when the contacts are at 45°, shall be .707 X where X is the resistance of half the arc, which is X° long, and has, therefore, unit resistance per degree.

Let X equal the length of half the arc in degrees, and let us suppose its resistance per degree to be 1. Then (see formula 3) resistance equals

$$.707\,X = \frac{4X^2 - 4\,(45^2)}{4X} = \frac{4X^2 - 8100.}{4X}$$

$$\begin{aligned} 2.828X^2 &= 4X^2 - 8100 \\ 1.172X^2 &= 8100 \\ X^2 &= 6911 \\ X &= 83^\circ +. \end{aligned}$$

If the arcs are made of this length, it is a fact which may be easily proved that, for all other points on the arcs, the resistance of the circuit will be very nearly X multiplied by the sine of whatever the angle at which the telescopes may be placed; so that this plan affords a compensation sufficiently accurate for practical purposes, though not theoretically exact. Furthermore, if the two telescopes be converged, one being placed at, say, 45° and the other 47°, the resistance

will be very nearly X multiplied by sine 46°; so that the distance indicated, while not equal to $\frac{AB}{\text{sine ATB}}$ sine ABT or to $\frac{AB}{\text{sine ATB}}$, sine BAT is very nearly equal to $\frac{AB}{\text{sine ATB}}$ sine $\left(\frac{ABT + BAT}{2}\right)$ thus indicating the distance of the target, not from either end of the base line, but from a point which is nearly half way between them, though not exactly so.

In the practical installation of the range-finder the resistance of the leading wires is, of course, considered, and this shortens the length of the arcs below ъ3°. Usually, the length of the wires is gotten empirically, in constructing the range-finder, simply adding or subtracting wire in the battery circuit until the galvanometer indicates proportionately to sine $\left(\frac{ABT + BAT}{2}\right)$. After this has once been done, nothing but an accident to the instruments will probably render it necessary to change it. A certain amount of resistance wire is, however, usually left in the battery circuit, so that, should necessity arise, this can be varied at any time, adding resistance, should the galvanometer deflection increase too greatly at 45°, and subtracting resistance, should it not increase sufficiently.

The earlier range-finders followed Fig. 8 very closely in design, the telescopes carrying contacts that pressed on the wires, which were in the form of arcs. Certain practical difficulties with this form led, however, to the form hereinafter described, which, though less simple in construction, requires less care and is more accurate.

The following description applies to the apparatus illustrated in Figs. 1, 2, 3, etc.

DETAILS OF CONSTRUCTION.

It is of prime necessity that the galvanometer needle shall not be deflected when the two telescopes are relatively parallel, no matter what their positions may be on the conducting arcs *h h'*, Fig. 8. This, however, presupposes an exact equality in resistance per unit length of the branches *a, b, c, d* of the bridge; or rather of that part of them, namely, the wires *h h'*, over which the telescopes move. This condition is, however, one that is seldom encountered, for, in practice, although the telescopes may be parallel, the galvanometer almost always shows some slight deflection, the amount of which may vary in accordance with different positions of the telescopes upon their arcs. Hitherto it has been possible to avoid this error in the

instrument only by careful selection of the wire forming the conducting arcs *h* and *h'*, in order to obtain such pieces of wire as are uniform in resistance per unit length.

Still another difficulty which has been encountered in practice is the error arising from temperature affecting the conductors on one side of the bridge differently from those of the other side; so that even if the telescopes stand parallel, and even if the conducting arcs *h h'* be physically the same, still there will be a deflection of the needle.

The principal object of the present mechanism is to provide means for eliminating both of the foregoing sources of error; and to this end it consists in apparatus whereby, first, the position of the contact points upon the conducting arcs, *h h'*, may be automatically changed so as to compensate for any error due to the resistance of the bridge branches not being uniform per unit length, and, second, in a device for modifying the lengths of the bridge arms to compensate for temperature error.

In the accompanying drawings Fig. 1 is a plan view of the instrument. Fig. 2 is a vertical section on the line 2 2 of Fig. 1. Fig. 3 represents, diagrammatically, the general arrangement of the instrument embodying the construction hereinafter more particularly explained. Fig. 4 is a plan view of the temperature correcting device. Fig. 5 is a side elevation of the same. Fig. 6 is an enlarged, detailed, cross-sectional view of the contact arm controlling mechanism. Fig. 7 is a plan view of the adjusting pins and their supporting bar. Fig. 8 represents, diagrammatically, the typical arrangement of the range-finder. Figs. 9, 10 and 11 are Wheatstone bridge diagrams illustrating the changes in position of the contact points *e f*. Similar letters of reference indicate like parts.

The term "instrument" in the following description means one of the two instruments which together are united in Wheatstone bridge with the galvanometer and battery, all of these appliances combined forming the complete range-finder.

Each instrument is mounted upon a metal standard, 1, Fig. 2, which is of such size as to bring the telescope L at a proper height for the eye of an observer. On the pedestal, 1, is rigidly secured a circular Table, 3, and around the edge of this table is a worm-wheel, 4. The mechanism of the instrument is supported upon a metal plate, 5, which in turn is supported on a pivot, 6, seated in pedestal 1. The rear side of the plate 5 is semi-circular in form and is provided with a downwardly-turned flange, 7. Secured on the under side of Table 4 is a pointer, 8. On the flange 7 may be marked a scale of any suitable divisions, by means of which and the pointer 8 the plate 5 may

be adjusted in any definite position. Journaled on the under side of the plate 5 is a shaft, 9, which carries a worm, 10, engaging with the worm-wheel 4. The shaft 9 has a crank handle, 11, so that by turning said handle 11, and because the worm-wheel 4 is fixed, the worm 10 is caused to move around wheel 4, and in this way the supporting plate 5 is caused to rotate over any desired angle upon its pivot 6. Upon the plate 5 are bearings, 14, which rest upon insulating blocks, 15. These bearings support metal pins, 16, upon which pins the rheostat cylinder 17 rotates. Each pin, 16, is secured to a metal cap, 18. The caps are internally threaded and receive the ends of cylinder 17. In the cylinder periphery is a spiral, in which is wound the conducting wire *h*, having its ends connected to caps 18. On the brackets 14 are binding posts, 19, which communicate by leaf springs, 20, with the pins 16. When the wires *a* and *c* are connected to these posts there is circuit from one binding post 19 to its leaf spring 20, to pin 16, to one cap 18 through the conducting wire *h*, to the other cap 18, leaf spring 20, binding post 19 and wire *a*. The shaft, 9, is pivoted at one end and a coil spring presses the other end towards the worm wheel 4, so as to make the worm, 10, engage firmly and without lost motion. Another coil spring around the shaft, 9, prevents lost motion between the shaft, 9, and its bearings.

Upon one end of cylinder 17 and insulated therefrom is a gear wheel, 21, which engages with the gear wheel 12 on and insulated from the shaft 9. Therefore, when the handle 11 is turned, the mechanism so far described produces both a rotation of the supporting plate 5 on its pivot 6, and also a rotation of the cylinder 17.

Also on plate 5 are two other brackets, 23, supported upon insulating blocks, 24. In these brackets is journaled a shaft, 26, the periphery of which is screw-threaded and which also carries a pinion, 27, insulated from said shaft, which engages with the gear wheel 21. Electrical communication is made through one of the brackets 23 to the shaft 26, one of the wires leading from the battery *i* being connected to the bracket.

Upon the shaft 26 is a nut, 29, having an arm, 28, which terminates in a contact point, *e*, of platinum. This point enters the spiral groove on the cylinder 17 and bears upon the wire therein. Connected to the arm 28 and below its pivot point is a leaf-spring, 29* (the nut being recessed to receive said spring), the effect of which is to force the contact point *e* down into constant touch with the wire *h*. On the rear side of the nut 29 is a small roller, 31, and carried on the under side of said nut by a spring-arm, 32, is another roller, 33. A third result, which is caused by the rotation of the handle 11, is the rotation through the gears 21 and 27 of the screw shaft 26 and

the consequent movement of the contact point e along the spiral in the cylinder 17 the pitch of the screw on shaft 26 and the pitch of the thread on cylinder 17 being the same. The mechanism so far described and that which will be described hereafter is all enclosed in a box, 34, upon the top of which the telescope L is mounted in suitable standards, 35.

Let it now be supposed that the two instruments are placed at opposite ends of a base line passing through the axis of the two cylinders 17; also that the contact points e f in the two instruments are at the middle points of the wires h h', wound upon the cylinders 17. The two telescopes L and L′ will then be parallel in a position at right angles to the base line, and, therefore, directed at some point in space infinitely distant. The galvanometer will then show no deflection, the needle indicating the infinity mark. Following the conditions represented in Fig. 8, let one instrument remain in this condition, with the telescope pointing toward the object T, while the other telescope is trained upon the object. To this end the handle is turned, thus rotating simultaneously the supporting plate 5, and thus training the telescope upon the object, while at the same time, through the gearing already explained, the cylinder 17 and the screw shaft 26 are both rotated, causing the contact point e to move over the wire h in the cylinder 17. a distance which is obviously proportional to the amount of angular train of the telescope. Therefore, when the telescope shall have been trained upon the object T, the contact point e in that instrument will have moved over a distance on the wire h represented by the distance E C in Fig. 8.

We have now come to the means for compensating for non-uniformity in the resistance of conducting wires h h' per unit length, but before considering the details of the mechanism it is necessary to explain more fully its principle. If, in the simple form of Wheatstone Bridge, shown in Fig. 9, the four branches are exactly equal one to the other ($a = b = c = d$), then, if the two contact points e and f be placed exactly at the angle between a and b and c and d, the bridge will balance, because $a\,c = b\,d$. If the contact points e f be moved along the branches a d for equal distances, and if the branches are assumed to be of uniform resistance, said points will then have moved over equal resistances, represented by r, Fig. 10. The bridge will still be in balance, for $(a - r)\ (c + r) = (b + r)\ (d - r)$, because (since $a = b = c = d$) this may be written $(a - r)\ (a + r) = (a + r)$ $(a - r)$, which is self-evident.

It is obviously easy to place the contact points c and f, as shown in Fig. 9, upon the wire h on cylinder 17, so that the resistance in a shall equal the resistance in b, and so that the resistance in c shall

equal the resistance in d. This is a mere matter of adjusting these points until that condition is produced; but we cannot assume that because $a = b$ and $c = d$, that $a = b = c = d$, or that $a + b = c + d$. In Fig. 10 it has been supposed that for equal distances moved over by the contact points e and f, the resistances are likewise equal—that is, both equal to r. If, however, this equality of resistance does not prevail, by reason of non-uniformity of the wires, we shall have a different condition, which is illustrated in Fig. 11, in which, although the contact points e and f have been moved over the same distances over the wires a and d, the resistances corresponding to these distances are m in one case and n in the other.

In order that the bridge may balance we must have

$$(a - m)(c + n) = (b + m)(d - n); \text{ or}$$

$$ac + an - mc - mn = bd - bn + md - mn,$$

which by cancellation gives

$$(a + b)\, n = (c + d)\, m; \text{ or}$$

$$\frac{a + b}{c + d} = \frac{m}{n},$$

which means simply that the sum of a and b and of c and d must be proportional to the resistances corresponding to the distances over which the contacts e and f are moved (or, in other words, to m and n), in order that the bridge may balance. Hence, if after said contracts are moved, the bridge does not balance, it is because a correct ratio of m and n has not been obtained, and, therefore, the distance represented by either m or n must be increased or diminished by causing an adjustment of the contact points $e\,f$ until the galvanometer no longer deflects.

In practice, however, as already explained, the mechanism which trains the telescopes upon the object and that which moves the arm 28, carrying point e over the wire h, is actuated simultaneously by the crank 11. Consequently, if after, by this means, the telescopes were laid parallel in the two instruments, and the points $e\,f$ correspondingly placed on the wires $h\,h'$, there should still be found a deflection of the galvanometer g, the points $e\,f$ could not be adjusted to new positions (thus varying m or n) by handle 11 without moving the telescopes out of parallelism. Therefore, points $e\,f$ must be moved independently of the telescopes in order to give the proper relation of m and n.

Obviously in Fig. 11 the contact points e and f may be moved for distances not only which have corresponding resistances $m\ n$, but for any other distances, say such as have corresponding resistances $m'\ n'$; hence, there must be a proper ratio between $\frac{m'}{n'}$ as well as between $\frac{m}{n}$,

and so on, in order that the galvanometer will show no deflection when the two telescopes occupy similar positions; that is, when they are parallel.

Upon standards 36, on the plate 5, is a transverse bar 37. In this bar is disposed a number of pins, 38, having their lower ends, 39, turned at right angles. The pins may be separately adjusted vertically in the bar 37, and each pin is secured in place as adjusted by means of its own set screw, as 40. The pins are also placed as closely together as possible (Fig. 7), being staggered in position, so that their lower ends, 39, form a substantially continuous guide-way, on the upper side of which rests the roller 31, on nut 29, and against the lower side of which bears the roller 33, also on said nut. When the surfaces of the ends 39, of the pins 38, lie all in the same horizontal plane, then the rollers will travel along said surfaces as the nut 29 moves along the screw shaft 26 without causing any vibratory or tilting movement of the nut 29 on its shaft. But if said ends are not in the same plane, but, in fact, form a cam surface (by reason of different vertical adjustments of the pins 38, in the bar 37), then the rollers 31 and 33, in following the irregular surface, will cause more or less of a tilting of the nut 29, and the result of such a tilting is the moving of the end e of the arm 29 forward or backward upon the wire h in the cylinder 17.

Now, if one pin, 38, is provided for every successive degree of angular movement given to the telescope L by the handle 11, then clearly the position of the contact point e on the wire h will be governed by the vertical adjustment of that pin in the bar 37; and, hence, as the telescope moves over its entire azimuth, and as the point e simultaneously moves over the wire h, the position of the point e, on said wire h, will be slightly advanced or retarded for every degree of angular movement of the telescope.

This will be better understood by considering the practical mode of adjusting the apparatus. Let both telescopes be adjusted parallel with the points e f, at the middle parts of the cylinders 17, as shown in Fig. 3, so that the galvanometer g gives no deflection. The handles 11 in both instruments are now turned to change the angular position of the telescopes one degree (or any other angle), and by reason of the gearing provided, to rotate the cylinder 17 one revolution. The contact point e will then be moved over a certain distance on wire h in one instrument, which distance may have in this instrument the corresponding resistance m. The contact point f will also be moved over a certain distance on wire h', which may have the corresponding resistance n. If the ratio $\frac{m}{n}$ is correct, the bridge will balance and the galvanometer g show no deflection. But assume the galvanometer

does deflect, it is therefore necessary to vary m or n. The rollers 31 and 33 are now respectively above and below the first pin of the series 38. This pin in either instrument is therefore to be raised or lowered in its bar, so as to cause the point e to move forward or backward on the wire h until the galvanometer shows no deflection. This pin is then secured as adjusted by its set screw. The proper relation of m and n for that position of the telescopes has now been found and the apparatus permanently adjusted thereto.

The telescopes are then changed in angular position another degree, and the cylinders rotated another revolution. The rollers 31 and 33 are now above and below the second pin of the series, 38. The contact points e and f have moved over distances having corresponding resistances m' and n'. The galvanometer deflects. It is necessary to vary m' or n'. The second pin is raised or lowered to adjust the point e until the galvanometer shows no deflection, and this pin then is secured by its set screw. The proper relation of m' and n' for the second position of the telescopes has been found, and the instrument permanently adjusted thereto.

So on for other positions of the telescopes, differing successively by one degree, until finally all of the pins 38 have been adjusted, and their lower ends 39 produce a more or less irregular surface—the irregularity of which reflects, so to speak, the variations in the resistance per unit length of the wires h h', which, of course, are the only parts of the bridge branches traversed by the contact points e f. As long as these wires remain in the instruments it is not necessary to readjust the pins 38, because always thereafter (barring accidents) the contact points e and f controlled by the pins, in the manner described, will automatically be adjusted to preserve the proper ratio $\frac{m}{n}$, $\frac{m'}{n'}$, etc., for every position of the telescopes varying by one degree. It is, therefore, unnecessary to expend time in making wires h h' of uniform resistance per unit length, or in selecting such wires. All that is needed is that they shall, in the beginning, approximate the proper condition in this respect, and any error is met by the correcting mechanism just described.

So far, in considering the general expression $\frac{a+b}{c+d}=\frac{m}{n}$, we have considered only the effect of variations in resistance, per unit of length, as causes disturbing the bridge balance ; and means have been explained for compensating, or correcting, for this source of errors. But it will be plain that still any cause acting upon either the numerator or the denominator of the fraction $\frac{a+b}{c+d}$ will throw the bridge out of balance. Such a cause may result from temperature influences affecting the resistance of the branches $a+b$ differently from that of the branches $c+d$, such as one instrument getting hotter than the

other. So, for example, the resistance of $a+l$, or its conducting wires, may increase; or that of $c+d$, or its conducting wires, may diminish, or *vice versa*. We have simply now to compensate for the above source of error by suitably modifying the lengths of the bridge branches. Thus, if the resistance of $a+b$ becomes too small, we must increase the length of $a+b$, while diminishing that of $c+d$. For this purpose the "corrector" is provided, which is represented in the diagram, Fig. 3, and also in detail in Figs. 5 and 6. As shown in Fig. 3, 41 and 42 are arcs of wire. The arc 41 is interposed between the bridge branches b and c; the arc 42 between the branches a and d. Over the arcs sweep the contact fingers 43 and 44. With the fingers 43 and 44 is connected the galvanometer g. If the fingers 43 and 44 be both considered as moved to the right of the drawing, Fig. 3, then obviously the length of the branches a and b will be increased, while that of the branches C and d will be diminished. If said fingers be moved to the left, c and d are increased and a and b diminished. If, now, having adjusted the apparatus in the manner before described for the ratio $\frac{m}{n}$, we find that at some subsequent time, or under different local conditions, the galvanometer nevertheless shows a deflection, we know that the difficulty is due to extraneous influences, and not to any alteration physically in the conductors. Therefore, we simply move the contact fingers 43 and 44 equally in the proper direction to cause the galvanometer deflection to disappear.

In practice, and as shown in Figs. 5 and 6, the wires 41 and 42 are mounted upon the periphery of a disk, 45, of insulating material, supported on a suitable standard 46. Through the disk 45 passes a shaft to which is rigidly secured at one end an arm, 47, carrying the contact finger 43. Loose upon said shaft on the other side of the disk is an arm, 48, carrying the contact finger 44, said finger being held on said arm and capable of being tightly secured thereto by the milled head 49. On the side of the disk 45 is a groove, 50, of dove-tailed shape in cross-section, in which groove is a similarly formed sliding piece, 51, provided with a clumping screw, 52, which passes through the arm 47. The fingers are adjusted in place on the wires 41 and 42, either together or separately by hand, and after adjustment, both are clamped in place by the screw 52. The bridge branches a, b, c, d connect in the manner already described to binding posts 53, which posts are electrically connected to the ends of the wires 41 and 42.

Loose upon the shaft 9 are two disks, 54 and 55, to either of which the handle 11 may be applied. These disks are held with sufficient rigidity to allow of the shaft being turned by the handle, by means of springs, 56, which are held against their faces by screws, 57. The object of this construction is to prevent injury to the apparatus

in case the operator should cause the parts to come to the limit of their movement suddenly, in which case the force applied to the handle 11 would cause the disk to rotate on the shaft.

Also upon the shaft 9 is a disk, 58, graduated in minutes, in proximity to which is a stationary datum mark, 59, on plate 5. The scale already referred to on the flange 7 of plate 5 indicates the amount of rotation of the plate on its pivot 6, in degrees, and the disk 59 enables this rotation to be further measured in minutes of arc.

The wire on the drums (which are made of insulating material) permits of a movement of the telescope of 54° or more on each side of the middle position, and the rest of the resistance wire needed to make the circuit of the correct resistance is laid in four insulated coils under the temperature corrector.

The resistance of the circuit when the telescopes are at the middle points is about nine ohms, but it varies somewhat in different instruments.

The wire, which is a special alloy, is No. 22 American gauge, .024 inch diameter, which is about No. 23 English gauge.

The galvanometer usually employed as the reading instrument is of the Deprez d'Arsonval type, improved by Weston. The current traverses a light coil of wire wound in the form of a bobbin, and pivoted between the poles of a powerful steel magnet M, Fig. 12. It is held normally at a certain position of rest by two coil springs, one at each end of the pivot. The effect of a current traversing the bobbin is to move the bobbin towards such a position that it lies perpendicular to a line joining the poles of the magnet. This tendency of the bobbin is resisted by the coil springs, so that the needle assumes a resultant position in which the force of the coil springs exactly balances the magnetic force operating between the magnet and the current in the bobbin; and, according as the current is small or great, the deflection of the needle, opposed by the spring, will be small or great.

The galvanometer is usually a "milli-voltmeter," in which the difference of electric potential at its binding posts, necessary to produce a sufficient current in the bobbin to make the needle swing over the entire scale, is about thirty milli-volts, or thirty one-thousandths of one volt.

The galvanometer is mounted in a heavy brass case, of which the outside is shown in Fig. 13. The inside of this case is shown in Fig. 12. Besides the galvanometer itself, which lies on a thick hard rubber slab, there is a reversing switch, R, by means of which the direction of the current through the bobbin may be reversed, a push-button, P, by means of which the circuit may be broken or

closed through the bobbin, and a coil of german silver resistance wire, which is so wrapped in a spiral on the insulating cylinder, C, that, if this cylinder is turned, a greater or less amount of resistance will be put in circuit with the galvanometer. The current enters at binding post B, passes to push-button P, thence to flat spring F, thence to an insulated pin on C, to which is connected one end of the resistance wire that is wound on C. Thence the current passes by the traveling contact T to the reversing switch R, through the bobbin between the magnet poles, out by the binding post B′. Before entering the bobbin, and after leaving it, the current passes through one of the coil springs. Clearly the amount of resistance wire between F and the traveling contact T is in circuit with the galvanometer and makes it less sensitive; and this amount may be varied by simply turning the cylinder and thus moving T in one direction or the other.

The use of the reversing switch is to reverse the current in the galvanometer in case the needle deflects the wrong way.

The use of the push-button is to close the circuit in the galvanometer when desired. It has been found advantageous in practice to introduce this push-button, to prevent accidents to the galvanometer from sending excessive currents through it.

The use of the resistance wire on the cylinder is to increase or decrease at will the sensitiveness of the galvanometer; that is, to increase or decrease the deflections of the needle. The usefulness of this device will be explained further on, when the operation of adjusting the range-finder is described.

All this mechanism is mounted on the bottom of the case and on a stout hard rubber slab, which covers the bottom. The top of the case fits over it and makes a tight joint at its junction with the bottom. When the cover is put on, it automatically makes connection between the button R on its top and the reversing switch R below. Furthermore, the gear wheel S, at the end of the insulating cylinder C, is engaged by a gear in the end of a shaft turned by the thumb wheel S on the top. These arrangements render it easy to make all the adjustments without removing the top.

On the top is also mounted a standard which supports a telephone transmitter.

If it is desired at any time to remove the top of the case, take out the four screws on the bottom flange, take off the nuts on the binding posts B B′, and lift the top off carefully.

Do not do this except when necessary, because the mechanism of the galvanometers should be protected from the air as much as possible.

Another form of reading instrument, suitable for conning towers and other places protected from the rain, is shown in figures 12A, 13A and 14A. The galvanometer is secured in a water-tight brass box G, and the adjustable resistance C, temperature corrector K, reversing switch R, push button P and the telephones are placed on the same base so that all the parts are accessible and can readily be inspected. The whole is protected by a cover when not in use. The current from the contact fingers 43 and 44 on the temperature corrector passes to the two pivots of the revering switch R, Fig. 13A. Thence the current passes in one direction, or the reverse (according as the switch is moved to the right or the left), to the flat spring contact F, to the resistance wire which is wound on the insulating cylinder C, and on which F presses to the metal pivot of C, through the bobbin of the galvanometer to the push button P and back to the reversing switch R.

METHOD OF INSTALLATION.

The odd numbered instrument goes forward, the even numbered instrument goes aft. That side of each instrument which is graduated in degrees goes on port side. The forward, or odd numbered instrument, contains the wires *a* and *b*. The after, or even numbered instrument, contains the wires *c* and *d*. The telephone wires T and T″ are smaller than the other wires. The wires to *a* and *d* in each instrument are covered with yellow braiding. The wires to *b* and *c* in each instrument are covered with green braiding. The battery wires *e* and *f* in each instrument are covered with green-yellow braiding.

The wires, having been installed according to Fig. 14, secure the pedestals of the observing instruments firmly in position in such a way that the 90° marks will be as nearly as possible perpendicular to the base line. This can usually be done with an error less than one-quarter of a degree.

Secure the reading instrument in a place as dry and light as can readily be obtained. The conning tower or the pilot house is a good place; but it may be advantageous sometimes to put it near one of the observing instruments. The best place for the storage battery is usually the dynamo room. If found more convenient to place it elsewhere, arrange a switch and resistance near it, so it can be charged from the electric light current.

The longer the base line, the more accurate will be the indications of the range-finder. If possible, a base line as great as 60 yards should be obtained, though smaller bases are often used successfully. When the base is quite small, as is sometimes necessarily the case in monitors and in range-finders mounted on bridges that run athwartships, special instruments are constructed in which the necessary accuracy is obtained at the expense of the amount of movement. For bridge range-finders, for instance, the extreme movement may be only ten degrees each side of the central position. For bridge range-finders, naturally, a large angle of movement is not needed, as the ship can be kept pointed towards the enemy.

The pedestals having been secured in position and the electrical connections made, as per Fig. 14, the next step is

TO ADJUST THE RANGE-FINDER.

To do this, place both telescopes at 90°, and put both contact arms of the temperature corrrector near the middle of the arcs and clamp contact finger 43, Fig. 5. If the galvanometer needle deflects, showing that the "bridge" is out of balance, unclamp contact finger 44 on its shaft by turning thumb screw 49, and move 44 until the needle ceases to deflect. Then clamp finger 44 by turning thumb screw 49, being careful not to move the contact finger while clamping it.

Now move one telescope 1° away from 90°. The galvanometer should indicate a distance $= \dfrac{Base}{sine\ 1^\circ} = \dfrac{Base}{.01745}$

If it does not indicate this distance, add resistance to the galvanometer circuit, or take out resistance, until it does so indicate, by turning the milled head S, which turns the cylinder C, on which is wound the resistance wire.

Put both instruments at 50°. If the galvanometer does not point to infinity, unclamp contact finger 43 and move both contact fingers on the temperature corrector equally in the same direction until the galvanometer does indicate infinity.

To verify the electrical adjustment, it is well, if there is time, to set both instruments at 130° and at other points. If, in going to these other points, the galvanometer needle does move more than, say, $\frac{1}{32}$ inch, it shows that the adjusting pins inside the case need resetting. This rarely occurs, however.

Now, place one telescope at 45 and the other at 46°. The distance

indicated should be $\frac{Base}{sine\ 1^\circ}$ $sine\ 45\frac{1}{2}^\circ$. If the distance indicated be too small, add a little resistance wire to the battery circuit; if the distance indicated be too great, subtract resistance. If the point to which the needle goes on the scale does not differ more than $\frac{1}{32}$ of an inch from the point to which it ought to go, the resulting error is negligible; but, when there is time, as there always is in installing a range-finder, a much greater accuracy can always be obtained.

The range-finder being now adjusted electrically, point the telescopes towards some object, of which the distance is known, which is as nearly perpendicular to the base line and as distant as can be found. This object must not be more than 10° above the horizon. The best objects are the rising or setting sun, or the moon, or a very bright star, or planet, as their distance may be called infinite. If impracticable to get a heavenly body, select some sharply defined object, such as a mast, flagstaff or steeple which is as much as 2,000 yards distant, and abeam.

When the telescopes are kept pointing at the object, it will be found impossible to keep the cross-hairs exactly on the same point all the time. It becomes necessary, therefore, for each observer to notify the reader at the galvanometer when he is "on." The best way is for one observer to say "one, one," etc., through his telephone, whenever his vertical cross-hair is exactly on the point selected, and for the other to say "two, two," etc. The reader at the galvanometer, hearing both observers, notes when both speak together; and he knows that this is the time to read the galvanometer. He should not read, however, unless he sees that the galvanometer needle is steady at that instant; because, if the needle is not steady, it is evident that one observer or the other is not really "on." As soon as the reader becomes satisfied, however, that a good observation has been secured, he says "stop," through his telephone. Both observers stop moving their telescopes instantly.

If the distance indicated by the galvanometer is not the correct distance, it must be because the telescope supports are not secured at the proper points on the pedestals, or else because the pedestals were not placed correctly, since the range-finder has now been made correct, electrically.

In either case, turn one telescope directly down on the deck, without moving either telescope in azimuth, and mark on the deck carefully the places where the cross-hairs of the telescope seem to rest on the deck. To do this, as the deck is so close, it will be necessary to focus the telescope for this short distance, by turning the focusing

screw on the telescope, until it is correctly focused. Telescopes are correctly focused when the cross-hairs appear to remain fixed, and not to move to the right or to the left, when the eye is moved to the right or the left.

This reference mark having been made on the deck, move the same telescope in azimuth, by turning the wheel 54 or 55, until the galvanometer shows the correct distance. Then bring the telescope back to its mark on deck (without moving the wheel 54 or 55), by turning the telescope support on its base. To do this, slack up the holding down screws that hold the telescope support, and turn the horizontal adjusting screws on the telescope supports. The telescopes are now correctly lined with reference to each other, and it remains simply to re-secure the telescope support that has just been moved, and tighten the screws. Now, move one of the wheels, 54 or 55, until the galvanometer reads infinity (unless the galvanometer already reads infinity). The telescopes are now parallel. Now, move each telescope to 90° or some other convenient point, and make a reference mark where its cross-hairs seem to intersect. Make a memorandum of this and place the memorandum at hand near the instrument. The use of this reference mark is as a verification, in case, from any cause, in the future. the telescope standard should be bent, or the cross-hairs get out of position.

Always be careful to focus the telescope properly, in looking at any object near or far. The focus is practically the same for all objects more than 100 feet distant.

In soldering splices always use resin ; never use acid. Acid-made splices are not trustworthy ; and a little local battery is sometimes set up in the splice.

The most satisfactory time and place for adjusting or verifying the parallelism of the telescopes is at sunset, at sea, *bringing the sun abeam, and keeping the ship steady on a course while adjusting.* The operation does not require more than ten minutes, if the range-finder has been adjusted electrically beforehand.

USE OF THE RANGE-FINDER.

To use the range-finder, a crew is required of one captain and two observers. Intelligent apprentice would be suitable for this purpose. The captain reads the galvanometer and communicates directions to the observers, his transmitter being so placed that he can speak into it while watching the movements of the galvanometer needle. The

captain and the observers secure their receivers over their ears, passing the flexible metal bands over their caps.

Most of the points connected with the use of the range-finder have been mentioned under the head of Installing the Range-Finder. In the cases, however, when the ship or target, or both, are moving, considerable practice will be needed before the observers and the captain can so work together that good results can be obtained. The observers will find it impossible to keep their cross-hairs exactly on the same point of the target; and for this reason the needle will seldom be steady for more than a few seconds at a time. A little practice on the part of the observers, however, will soon teach them to work their telescopes quickly, and to say "one" or "two," exactly when their cross-hairs are "on." A break will always occur whenever either observer shifts his hand on the wheel 54 or 55, to get a fresh hold. With a little practice an observer can turn the wheel 54 or 55 half a revolution, without changing his hold, thus giving the telescopes a movement in azimuth of 1°. As the movement in azimuth of one telescope is almost exactly equal to that of the other telescope, a little practice will enable the two observers to change their hold on the wheels 54 and 55 at the same time. It is merely necessary for either observer (say No. 1) to say "change" when he finds it necessary, and for both observers to change at once. By following this plan, which can be done after a little practice, the galvanometer needle will be much more steady than it will be if the observers shift their hold without reference to each other.

One turn of the wheel 54 or 55 gives a movement of 2° to the telescopes; therefore, this wheel is graduated up to 120 minutes of arc.

When about to use the range-finder, verify first the lines of sight of the telescopes by pointing them at their reference marks, and then make the electrical adjustments. If in haste it will be usually sufficient to first put both at 90°, make the galvanometer reads "Infinity," and then converge the telescopes 1° and make the galvanometer read the distance corresponding, as explained above.

When through using the range-finder, disconnect the battery by disconnecting the wires from the binding posts A and B of the temperature connector, and one wire from the telephone receiver at the reading instrument.

CARE OF THE RANGE-FINDER.

Charge the storage battery every Saturday for ten hours or more with a current of about five amperes. The current of discharge,

when the range-finder is in use, is about one ampere. If, therefore, the range finder has been in use during the week more than fifty hours, the charging must continue longer than ten hours. Do not use the storage battery for any other purpose than for working the range-finder.

The liquid in the storage battery will slowly evaporate. Replace the amount lost once every month. The solution is sulphuric acid diluted to a density of 1.3 specific gravity, which is usually marked 1,300 on the hydrometer furnished with the range-finder.

The positive plate, which is of a dark-brown color, is wrapped in an asbestos envelope, and separated from the negative plate, which is of the ordinary lead color, by a perforated wooden separator. The plates are assembled, positive and negative alternately. The positive plates are connected together and the negative plates are connected together. The outside plates are the negative or pure lead plates.

Do not rub the instruments to keep them bright. It will be sufficient to wipe them off occasionally with an oily rag.

The only iron part in the observing instrument is the shaft, 9, which carries the worm, 10. This is made of steel and it is nickel-plated. The mechanism is not, therefore, liable to rust; but the brass box, 34, should be taken off once a quarter and the mechanism carefully oiled with watch oil or very fine machine oil.

Use the range-finder as frequently as possible, in order to give the range-finder crew expertness, and also to discover any defects that may develop. Be careful to disconnect the battery when it is no longer required. In one ship it was accidentally discovered that the storage battery had been discharging through the range-finder for three days. Not only was this a waste of current, but it is bad for a storage battery to be over-discharged.

In case it becomes necessary to prepare more liquid, be careful to pour the acid slowly into the water, and not to pour water into the acid, as this would occasion a violent evolution of heat. The liquid should just cover the tops of the plates. The liquid is of the proper density when the hydrometer floats at 1,300. If no hydrometer is at hand, make the liquid one part of commercial sulphuric acid to seven parts of fresh water.

PROBABLE DIFFICULTIES.

If the galvanometer needle does not move when the telescopes are converged, there is probably a break in the circuit at the galvanom-

eter, temperature corrector, accumulator or reversing switch. If the telephones work at this time the break is clearly not at the accumulator.

If the telephones do not work while the galvanometer does, there is a break in the telephone circuit, probably in one of the transmitters; though it may be that one of the connections is broken at a receiver.

If at any time the galvanometer indicates a distance incorrectly, while at the same time the range-finder is known to be adjusted electrically, the trouble is that one of the cross-hairs has become displaced or that the telescope supports have been moved. Either contingency is almost impossible, unless the instruments have been tampered with; and the reference marks on the deck are intended as a check whereby to discover such displacement should it occur.

If sounds can be heard through the telephones, but accompanied by rattling noises, there is a loose contact in the telephone circuit, or the battery circuit, or else the diaphragm of one of the transmitters is horizontal.

If the galvanometer needle moves to the left, when the telescopes converge, the current is going through it in the wrong direction. Move the reversing switch, R.

If the needle swings violently when the telescopes are converged only a few degrees, this is because the resistance has become excessive in one of the arms of the bridge, probably due to a broken wire or connection. This happens almost never, if the connections were originally well made.

In case of difficulty a careful man need not fear to take to pieces any part of the range-finder, including the galvanometer telephones and storage battery.

NUMERICAL DATA.

If the base is more than 60 yards and less than 90, three storage cells will be needed; if less than 60 yards, four—or more—will be required.

Weight of	forward observing instrument, complete.	159 lbs.
"	after " " "	159 "
"	reading instrument, complete..........	26 "
"	copper conducting wires	90 "
"	three storage cells in box..............	60 "
	Total weight of range-finder.............	494 lbs.

The adjustment mentioned at the bottom of page 9, whereby the contacts e and f are so placed that the resistance of a equals that of b, and the resistance of c equals that of d, is accomplished during manufacture before the other adjustments are made.

If the observing instruments are mounted on platforms on masts, do not make the marks on the deck which indicate the parallelism of the telescopes, as described in the middle of page 19, because the masts themselves move forward and aft a little as well as athwartships. Instruments mounted on masts, however, are safe from tampering, and will remain in adjustment if all parts of the telescopes and pedestals are firmly secured. It has not been found that masts twist to such an extent as to derange the adjustment of the range-finder.

If lost motion is discovered between the worm and the worm-wheel of an observing instrument, take out the spring which forces the worm into the worm-wheel and stretch it so as to lengthen it. To do this, take off the bearing of the shaft 9 under the plate 5 and the spring will be found inside the shaft bearing at that end of the shaft which has the green connecting wire. Be careful before doing this to set the instrument exactly on 90° and the micrometer wheel exactly on 120, and to put back the shaft exactly in the way it came out, so as not to alter the adjustment between the worm and the worm-wheel.

If the telephones sound too loud, put resistance (say about 50 ohms) in the telephone circuit.

The connecting copper wires between the resistance wires on the observing instruments are No. 6 American gauge, .162 inch diameter.

The resistance wires are of a special alloy, No. 22 American gauge, .024 inch diameter. The resistance of the circuit, when both telescopes are at 90°, is about 9 ohms.

The telephone wires are No. 16 American gauge, .05 inch diameter.

Diameter of bottom of pedestal, 16 inches.

Height of telescopes above bottom of pedestals = 59 inches. The height of the telescopes above the deck should be about 62 inches. The reason for not making the pedestals 3 inches higher is that a block of wood is nearly always required between the deck and the pedestal, to make the pedestal stand vertical; and, in some cases, where the deck is very uneven, this block must be as much as 3 inches thick. The pedestals are, therefore, designed to rest on blocks 3 inches thick at their middle points.

Length of telescopes		=	24½ inches.
" "	forward of trunnions	=	13½ inches.
" "	in rear " "	=	11 "
			24½ inches.

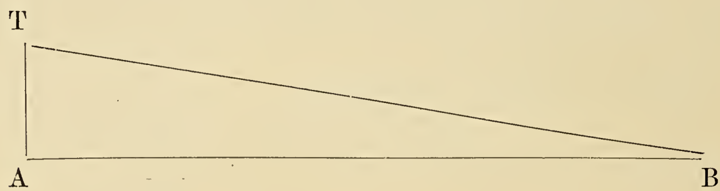
Diameter of reading instrument = 12 inches.

THE STADIMETER.

The stadimeter is an adjunct to the range-finder, and is designed to be used in concert with it, in such a way as to combine the portability and convenience of a one-observer instrument with the accuracy of a two-observer instrument.

As will be seen from the drawing, it is a modification of a sextant. It weights $3\frac{1}{4}$ pounds, and is of the same size as the ordinary sextant used in ships.

The stadimeter can be used to measure distance of objects whose height is known, or the height of objects whose distance is known, the micrometer head M being graduated in yards of distance, and the index bar B being graduated in feet of height.



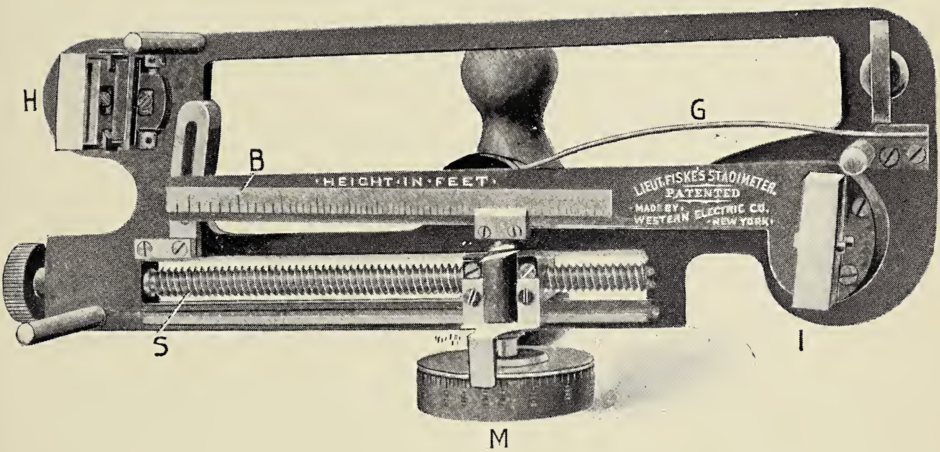
Clearly, from the diagram

$$AT = BT \text{ sine } ABT\text{; or}$$
$$BT = AT \div \text{ sine } ABT.$$

So that in either case, the measurement involves the measuring of sine ABT.

To accomplish this with the stadimeter, bring the reflected ray from the top of the object into coincidence with the direct ray from its bottom, by moving the index bar which carries the index glass I on its pivot, in the same manner as in using the sextant. To move this index bar, rotate the micrometer head M. The sine of the angle through which the index glass has been moved is clearly the amount by which the micrometer screw has moved longitudinally, divided by the distance from the pivot of the index bar B to the point on its edge where the force of the micrometer screw is applied. The german silver spring G presses the index bar against the end of the micrometer screw, and prevents lost motion.

Now, by the theory of the sextant, the angle between the reflected ray from the top of the object and the direct ray from the bottom of the object, is twice the angle through which the index glass has been moved out of parallelism with the horizon glass H. Therefore,


H
G
B
HEIGHT IN FEET
LIEUT. FISKE'S STADIMETER.
PATENTED
MADE BY
WESTERN ELECTRIC CO.
NEW YORK
S
I
M

assuming that for such small angles as those here used the sines of angles are proportional to their arcs,

$$AT = BT \times 2 \times \frac{\text{Length of movement of micrometer screw}}{\text{Distance from pivot to point of application of screw on index bar}};$$

or,

$$BT = AT \div 2 \times \frac{\text{Length of movement of micrometer screw}}{\text{Distance from pivot to point of application of screw on index bar}}.$$

As the length of movement of the micrometer screw longitudinally can be determined by the amount of angular movement of the micrometer head, it is plain that, if we know the pitch of the micrometer screw, the micrometer head can be graduated in units of distance and the index bar in units of height, or *vice versa.*

In the stadimeter this is done, and furthermore the point of application of the micrometer screw on the index bar can be varied at will. This is accomplished by mounting the micrometer screw on a block or nut which rides on the long screw S, so that by turning S the block or nut is moved in either direction.

To use the stadimeter to measure the distance of an object whose height is known, set the micrometer screw opposite that graduation on the index bar which indicates its height in feet, and bring into coincidence the reflected image from the top of the object and the direct ray from its bottom. The distance of the object in yards will then be found opposite the pointer on the micrometer head.

To measure the height of an object whose distance is known, assume the height to be 100 feet, and set the micrometer screw at the 100 mark on the index bar. Proceed as before, and read off corresponding distance (which may be called D) upon the micrometer head. Obviously,

$$\text{True height} : 100 = \text{true distance} : D.$$

$$\text{True height} = 100 \times \frac{\text{true distance}}{D}.$$

The stadimeter may now be set at the true mast-head height and used as explained above.

When employed in connection with the range-finder in a naval battle, take the distance of the enemy with the range-finder very carefully before the action has become hot, bringing her as nearly abeam as convenient, and when distant, say, 2,500 or 3,000 yards.

Find out her mast-head height simultaneously with the stadimeter, and set the stadimeter at this height and keep it ready for use. If afterwards the range-finder becomes disabled, or if it cannot be used for any reason, proceed with the stadimeter.

A moderately skillful observer can get eight observations per minute.

The foretop is a good place in which to use the stadimeter, the observer being connected by speaking tube or telephone with the person who telegraphs the ranges to the guns.

In fleet actions endeavor, if possible, to get exactly the mast-head heights of all the enemy's ships and make a memorandum, to be used when required.

RANGE INDICATING SYSTEM.

In the accompanying drawings, Fig. 17 is an electrical diagram illustrating the principle of the system, and showing one transmitting instrument T and ten receiving instruments I in circuit, each receiving instrument having an adjustable resistance in series with it, each adjustable resistance being in a metal box R. Fig. 18 shows in detail the mechanism by which in practice the contact C (Fig. 17) is moved along the resistance wire AB. Fig. 19 shows in detail the mechanism of the adjustable resistance inside of the box R; and Fig. 20 is a view of one of the receivers, or indicators, I (Fig. 17) with its resistance box R in position below it.

Referring first to Fig. 17, AB is part of a conducting circuit which includes the battery ı|ı|. T is a galvanometer which is connected in shunt with AB, one terminal being fixed at the point A and the other terminal, or contact, C, being movable along the conductor AB. It will be clear that when the contact C is moved along the conductor AB, the difference of electric resistance, and, therefore, of potential, between the points A and C will be varied, and consequently the extent of deflection of the needle or index of the galvanometer T may be controlled as desired, so as to cause said index to point to any scale-division or other mark or marks inscribed along its path. Connected in multiple arc with the galvanometer T are the two conductors marked + and —. Obviously these conductors will also be affected by the movement of the traveling contact C along the line AB, and will assume a difference in potential depending on the position of C on AB; so that if galvanometers I be connected to these conductors in the manner shown in Fig. 17, these galvanometers will respond to the movements of the contact C, for the same reason as does the galvanometer T. Furthermore, if all the galvanometers T and I be exactly similar, the needle deflections in all will be the same; and thus any indication caused in the galvanometer T will be repeated in the galvanometers I. Therefore, if T be the transmitting galvanometer, and if the instruments I be located at distant stations, it is plain that an operator at T, by adjusting the traveling contact C, can produce in his instrument a deflection which will instantly be repeated and shown at the distant stations in the receiving galvanometers I. It will be

apparent, however, that if the galvanometers I are differently located with respect to each other and to the galvanometer T, so that in the circuit of one there is a different resistance from that which is in the circuit of the others, or if from any cause any galvanometer becomes less sensitive, means must be provided whereby said galvanometer may be adjusted or regulated so as to compensate for any such differences or changes ; or in other words, so that each receiving galvanometer may be so regulated that its deflections, or indications, will correspond to those of the transmitting galvanometer T. In the practical construction of the system these means are provided, and consist merely of an adjustable resistance placed in series with each galvanometer, and secured in a water-tight iron box R.

Turning now to Fig. 18, which shows in detail the means employed for moving the contact C along the wire AB, we see that the wire AB is wrapped in a spiral groove traced in an insulating cylinder D. The ends of the wire are secured to german silver springs, *g*, *g*, secured at the ends of the cylinder near the axis. The binding posts A and B are insulated from the metal box J, and their ends are prolonged about half an inch inside the box into cylindrical pins, or axles, *a*, *a*, which fit in the cylinder D and press tight against the german silver springs, *g*, *g*, to which are secured the ends of the resistance wire AB. There is, therefore, a complete circuit from the binding post B to the german silver spring *g*, through the resistance wire that is wrapped around the cylinder, to the german silver spring *g* at the other end of the cylinder and thence to the binding post A.

The cylinder is revolved on the axle AB by means of the handle H, which turns the screw S, and the gear wheel G, and thence the gear wheel G′, which is secured to the cylinder D.

The contact C is secured to a stout piece of rubber that is secured on a nut N, that travels on the screw S. The pitch of the screw S and that of the spiral on the cylinder D are equal, so that, if the handle H be turned, the contact C will move with the nut N though insulated from it, and press successively on different parts of the wire. The contact C is connected by the flexible wire W to the binding post C′. If the battery ı|ı| be connected to the binding posts A B, and if A and C be connected to the binding posts + and — of T in Fig. 17, it is clear that the act of revolving H will cause the same effect as if the contact C were directly moved along the straight wire AB in Fig. 17.

Turning now to Fig. 19, which represents the adjustable resistance in the box R, we see that the construction is nearly the same as that in the transmitting box just described. The resistance wire is, how-

ever, connected to the german silver spring at the center of its cylinder at the left end only, as the right end of the wire is secured to the cylinder at the point P. The contact C″ is moved in the same way as is C in the transmitting box, Fig. 2, and is connected by the flexible cord W′ to the binding post C‴. The current enters at the binding post A′, passes thence to the german silver spring at the left end of the cylinder, to the resistance wire wrapped on the cylinder, to the contact C″, and thence to the binding post C‴. Clearly, if this apparatus be placed in series with any galvanometer I, and the handle H′ be turned, the resistance in series with I will be varied and the deflection of I correspondingly changed.

The place for the transmitter T is near the reading instrument of the range-finder, so that any distance read from it can at once be made to appear on the transmitter and simultaneously on all the indicators in the ship.

To adjust the apparatus for use, connect the battery and make the transmitter read, say, 2,950, or any other preconcerted number. Then make each receiver read the same number, by turning the thumb wheel H′. The apparatus is now ready; but if there is time, it is best to try a number of preconcerted numbers in succession. It is better not to use the even hundreds in adjusting, because the graduations half-way between them are finer and give better opportunities for exactness.

The resistance of each galvanometer is about 60 ohms.

The resistance of each box R or J is about 12 ohms.

The transmitting and indicating galvanometers are all similar, so that, in the event of accident to the transmitter, a receiver can be substituted for it. If this is done, however, it will be necessary, of course, to verify the adjustment of the instruments, in the manner above described.

The battery found most satisfactory for all this class of work is the "chloride" storage battery. It is extremely uniform in resistance and in electro-motive force, and requires almost no care, provided it be connected to the electric light circuit and charged once a week. To do this is very easy, as it only takes a little more trouble than is required to turn on an incandescent electric light.

Weight of each instrument complete, = 18 pounds.

Weight of two storage cells in box, = 40 pounds.

The instruments can be secured directly to a bulkhead. If desired, they can be graduated to work in a horizontal position.

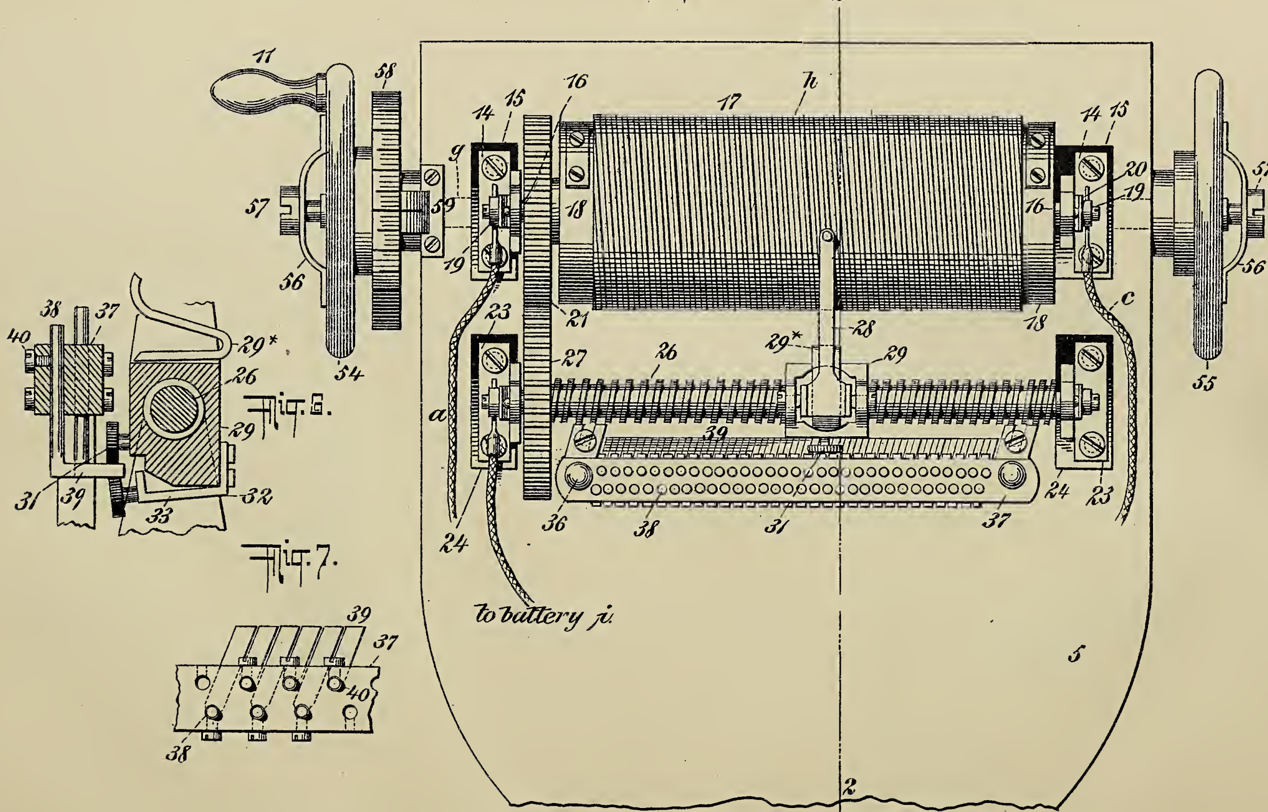
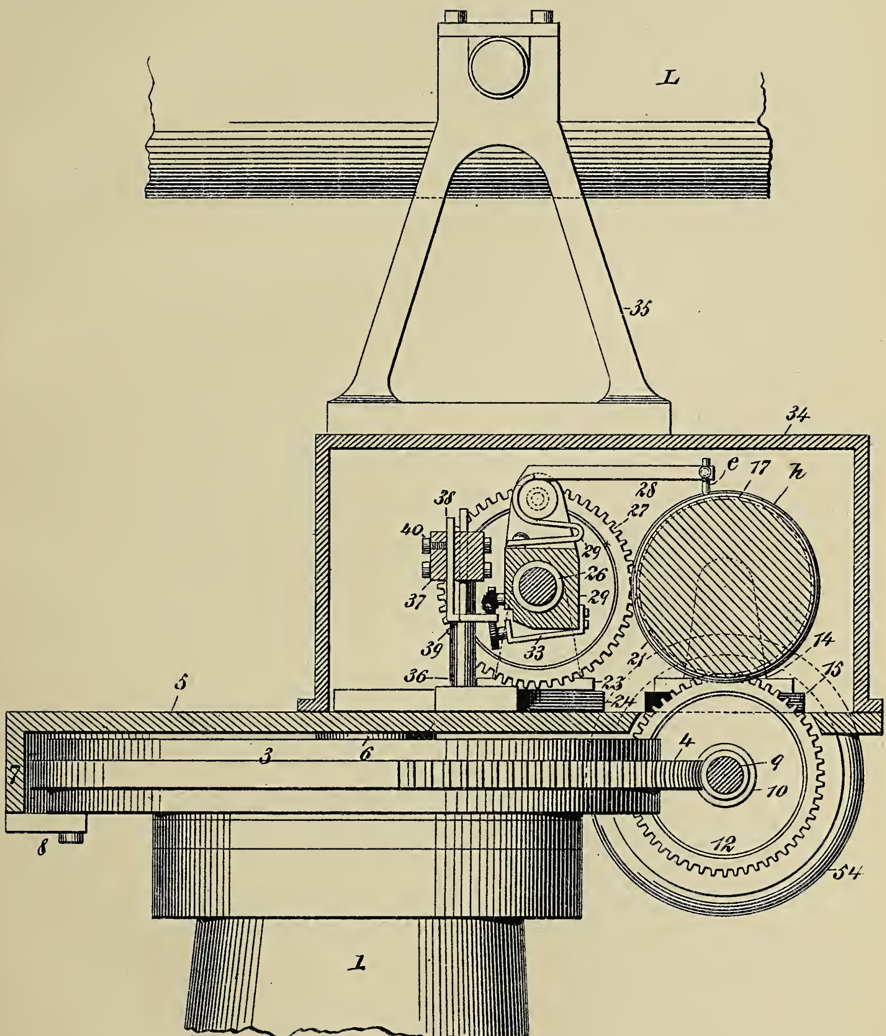


Fig. 1.

Fig. 6.

Fig. 7.

Fig. 2.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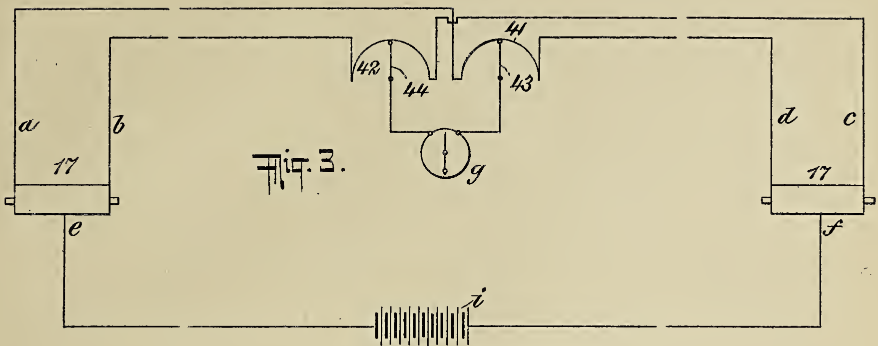


Fig. 3.

Fig. 4.

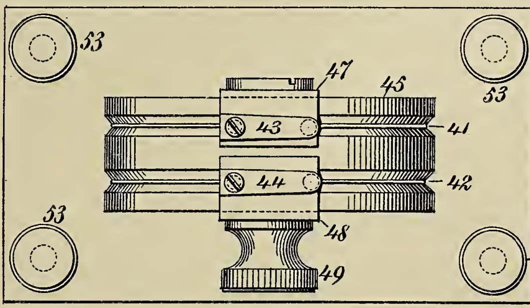
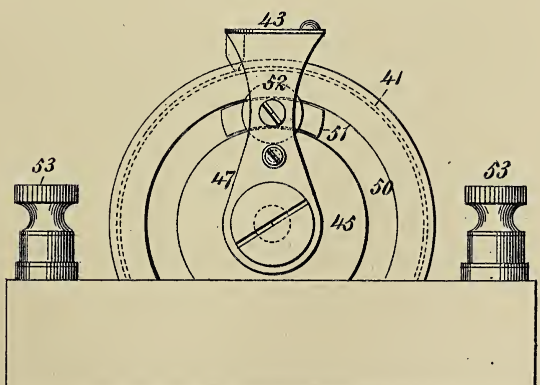


Fig. 5.



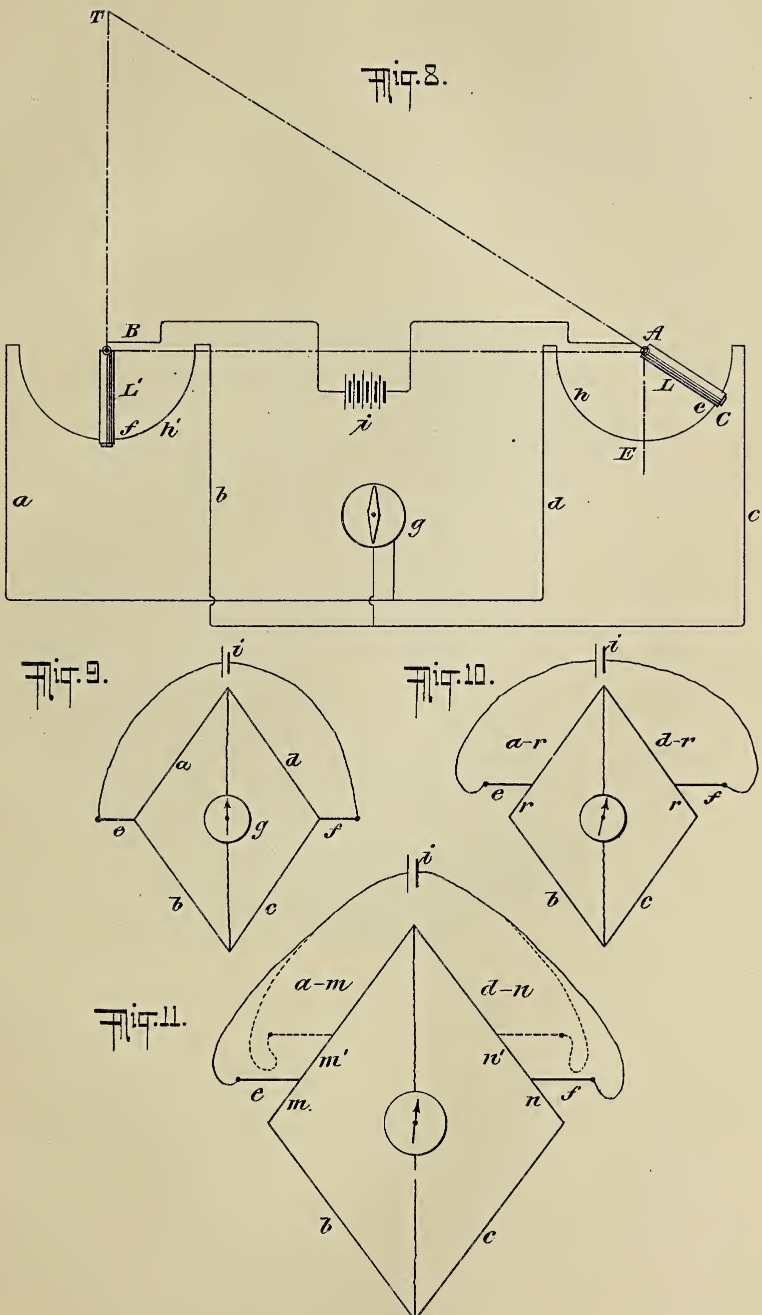


Fig. 8.
T
B
A
L'
L
f
h'
h
e
C
E
i
a
b
g
d
c
Fig. 9.
i
a
d
g
e
f
b
c
Fig. 10.
i
a-r
d-r
e
f
r
r
b
c
Fig. 11.
i
a-m
d-n
m'
n'
e
m.
n
f
b
c

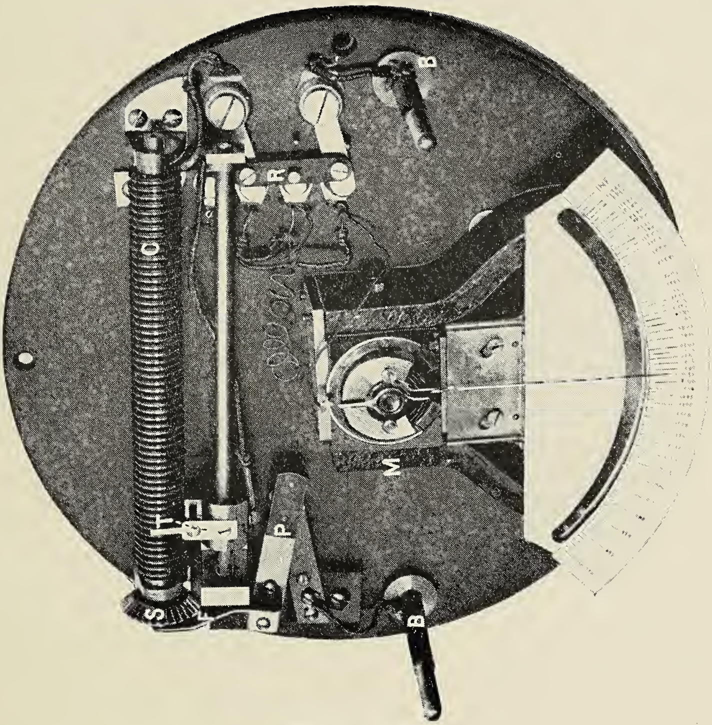


Fig. 12.

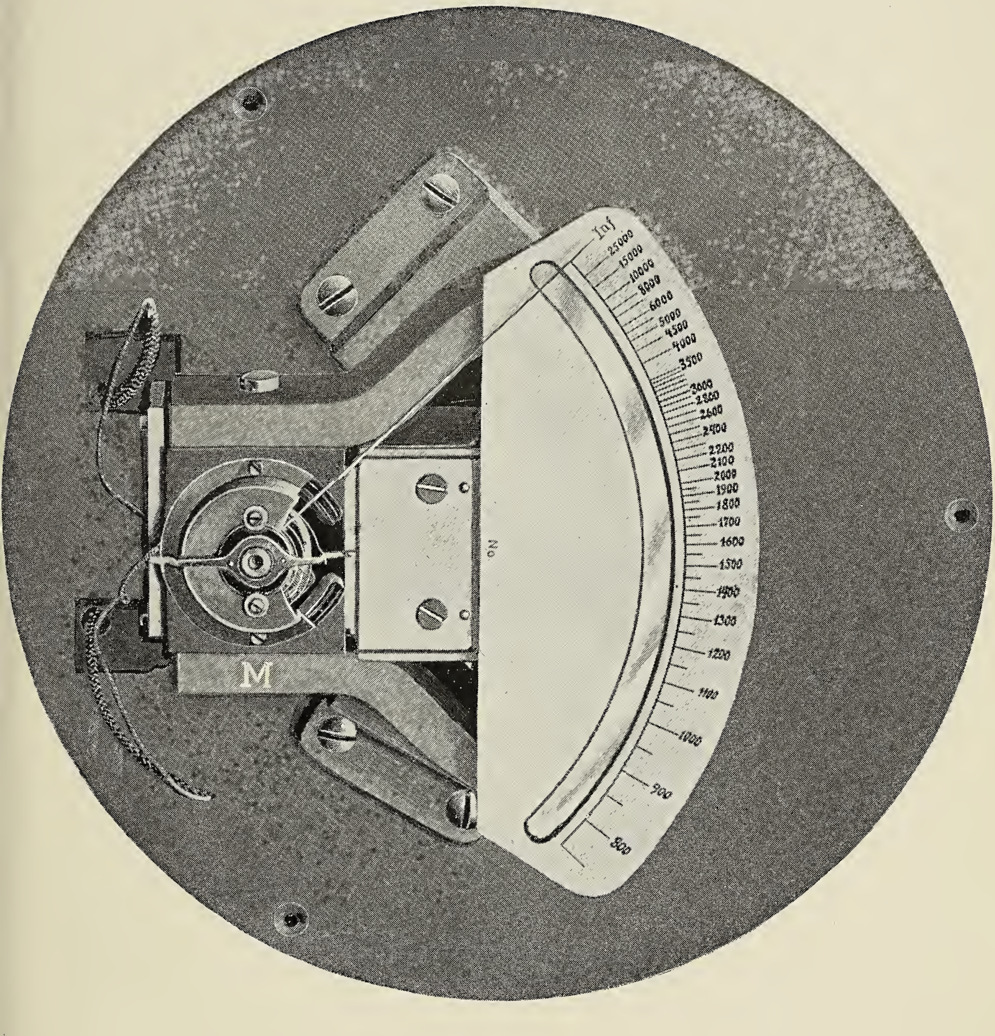

Inf
25000
15000
10000
8000
6000
5000
4500
4000
3500
2800
2600
2400
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
No.
M

FIG. 12 A

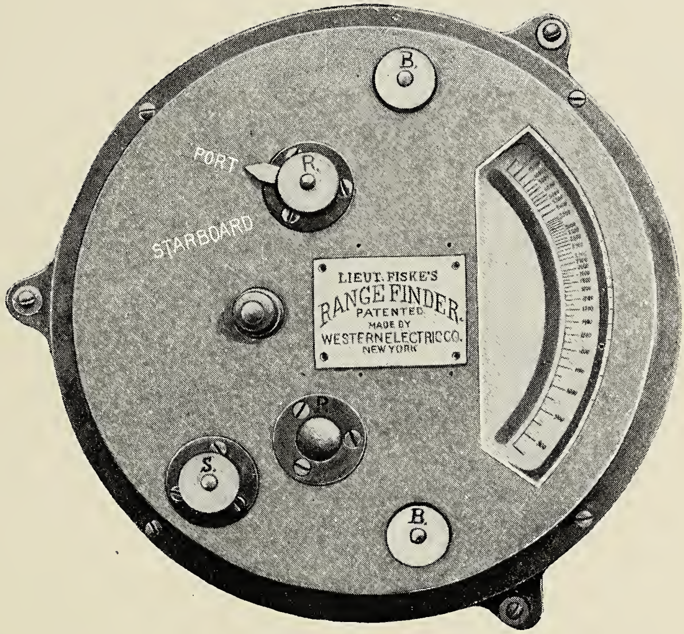

B.
PORT
R.
STARBOARD
LIEUT. FISKE'S
RANGE FINDER.
PATENTED.
MADE BY
WESTERN ELECTRIC CO.
NEW YORK
R.
S.
B.

Fig. 13.

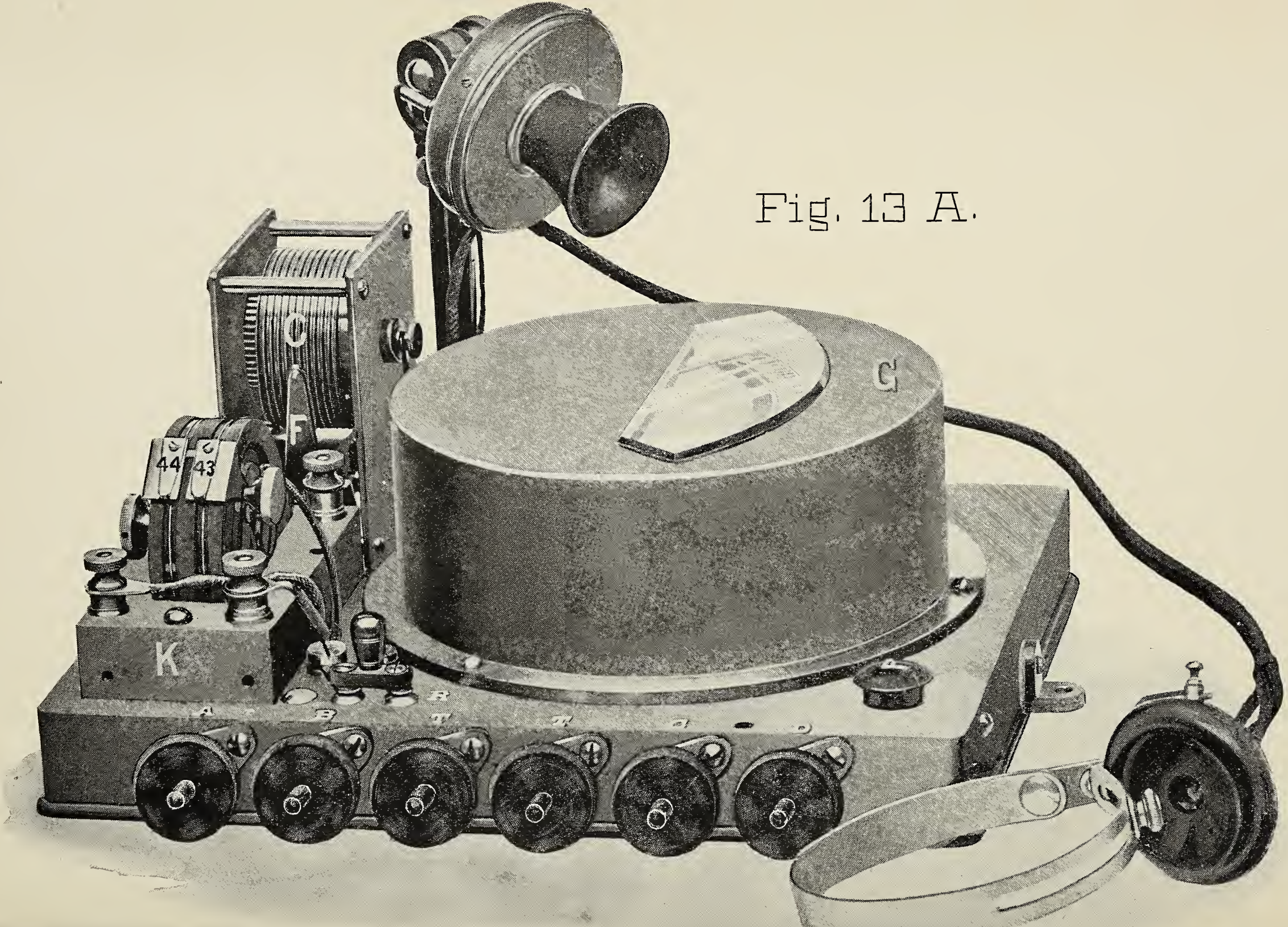
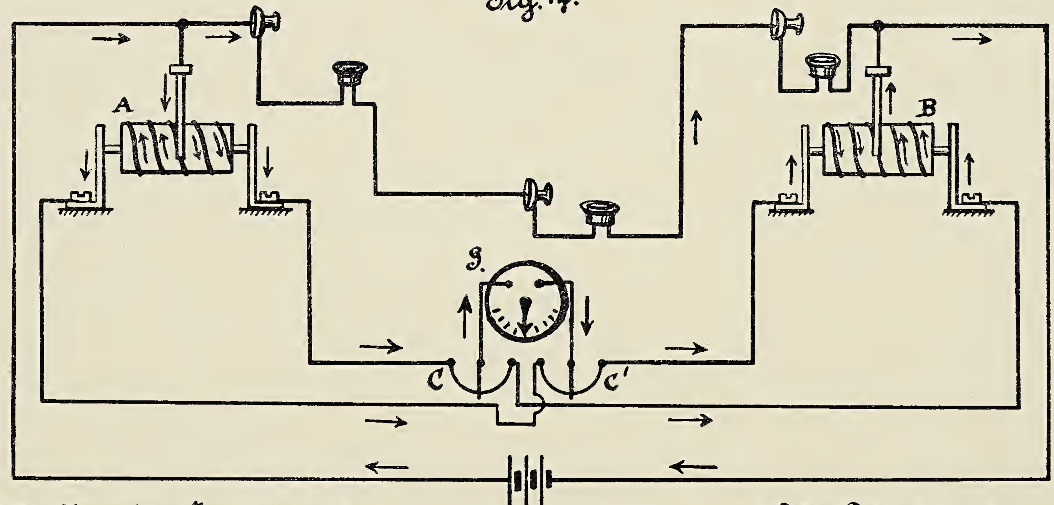


Fig. 13 A.

Diagram of Circuit of Range Finder.

Fig. 14.



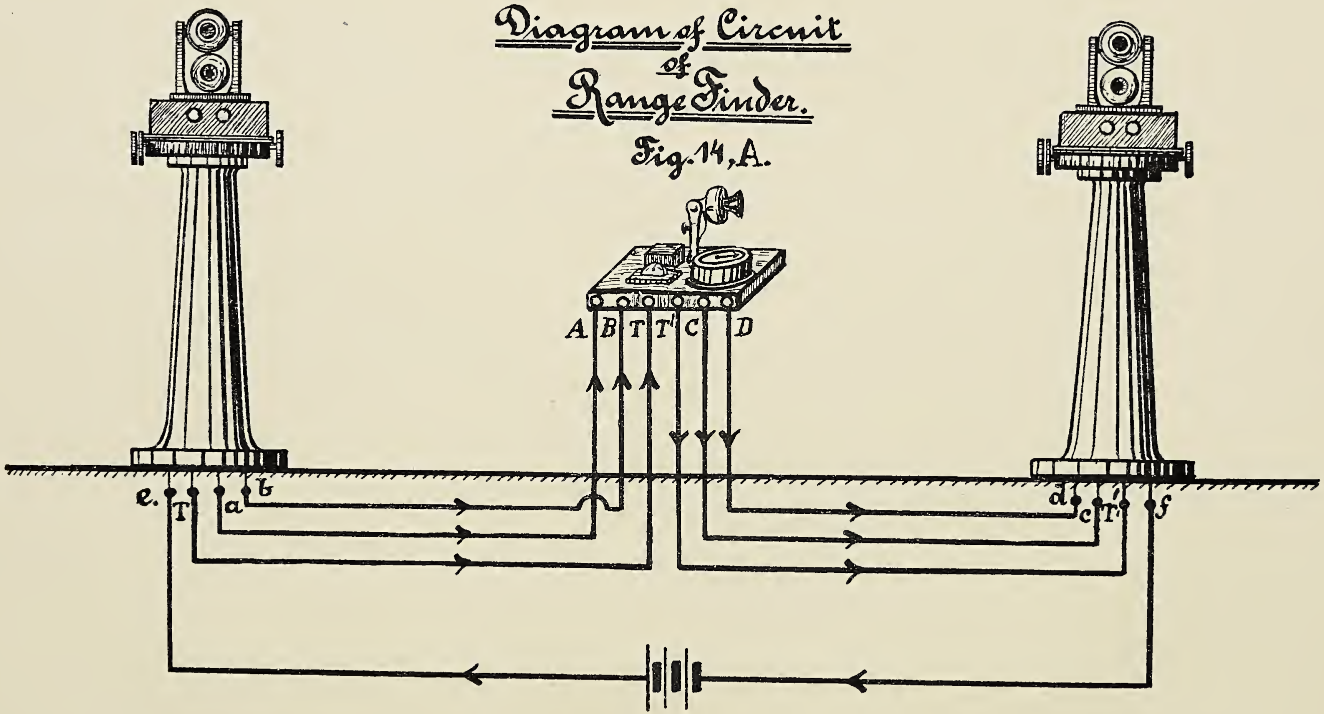
A & B = Observing Instruments.
C C' = Temperature Corrector.
G = Galvanometer or Reading Instrument.

= Telephone transmitter
= Telephone receiver.
= Storage battery.

Fig. 14.

Diagram of Circuit
of
Range Finder.

Fig. 14, A.



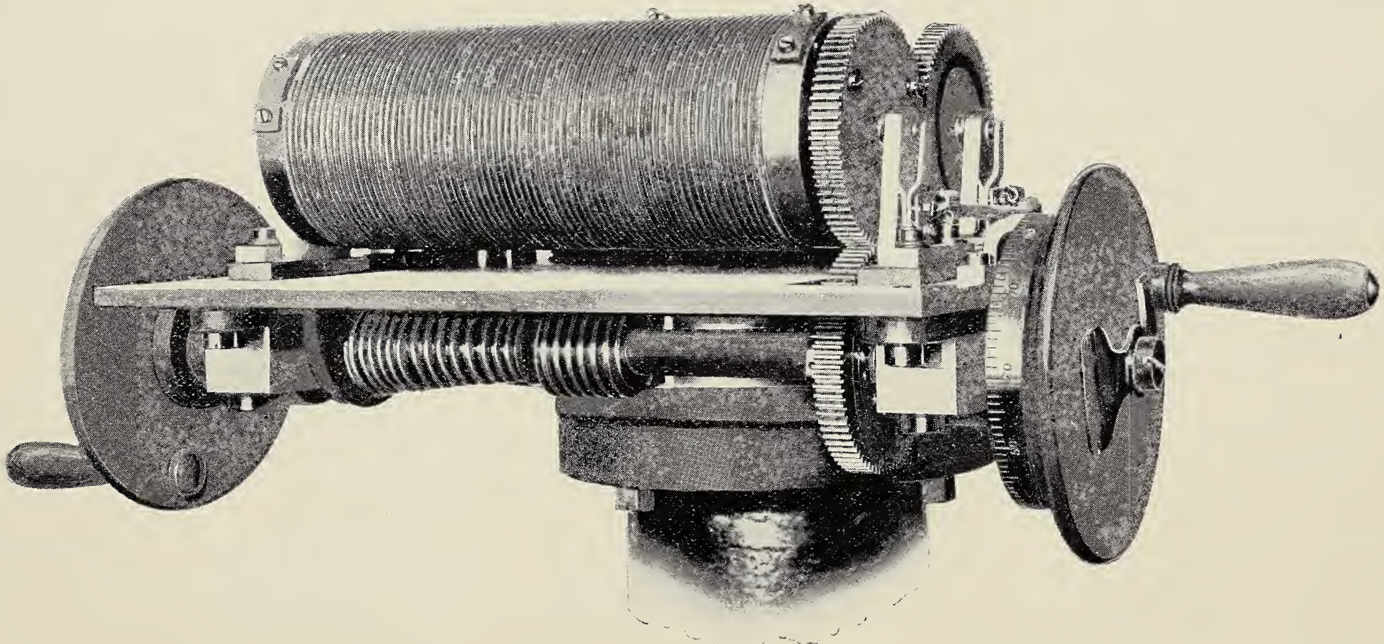


Fig. 15.

Fig. 16.

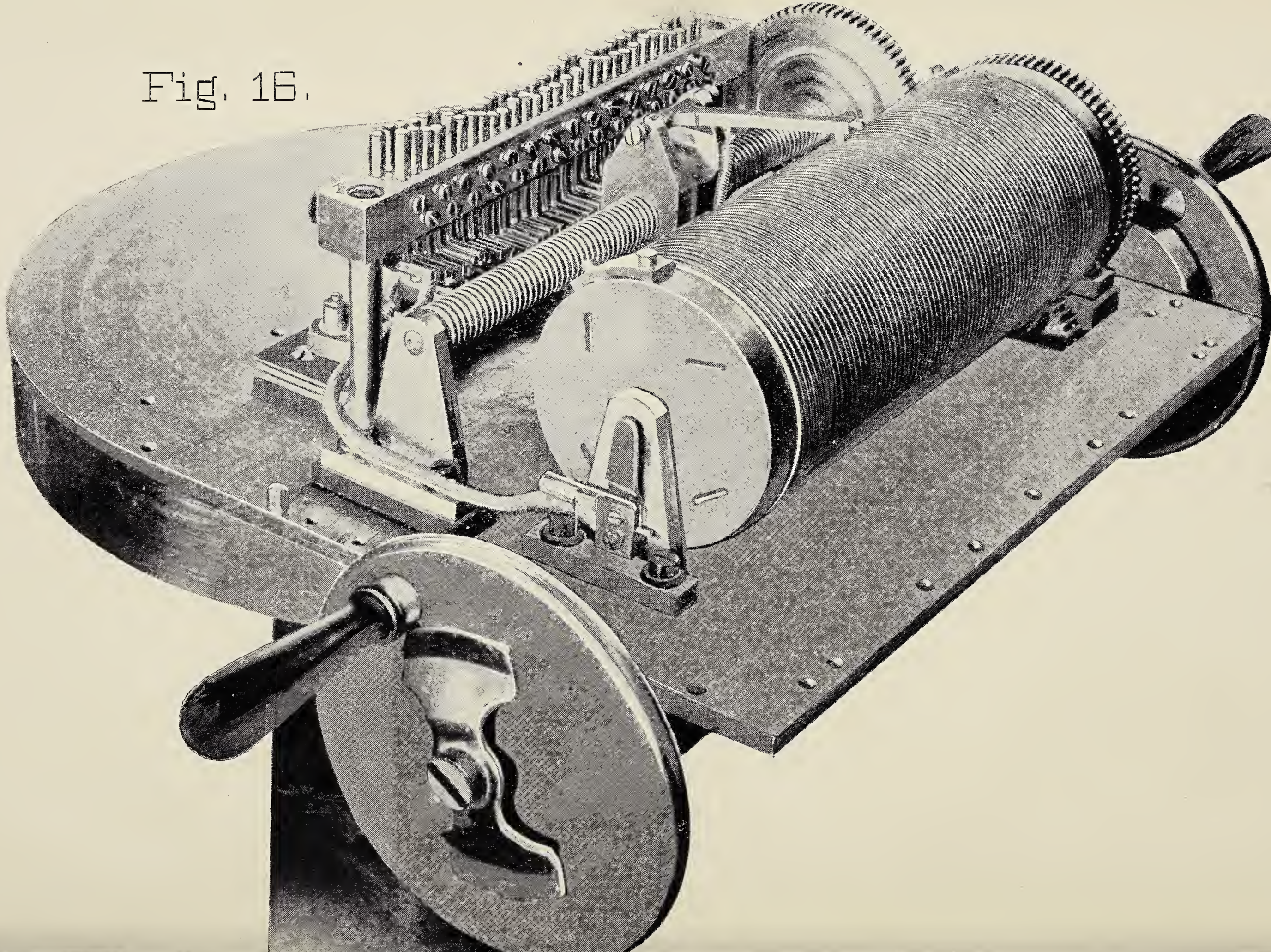
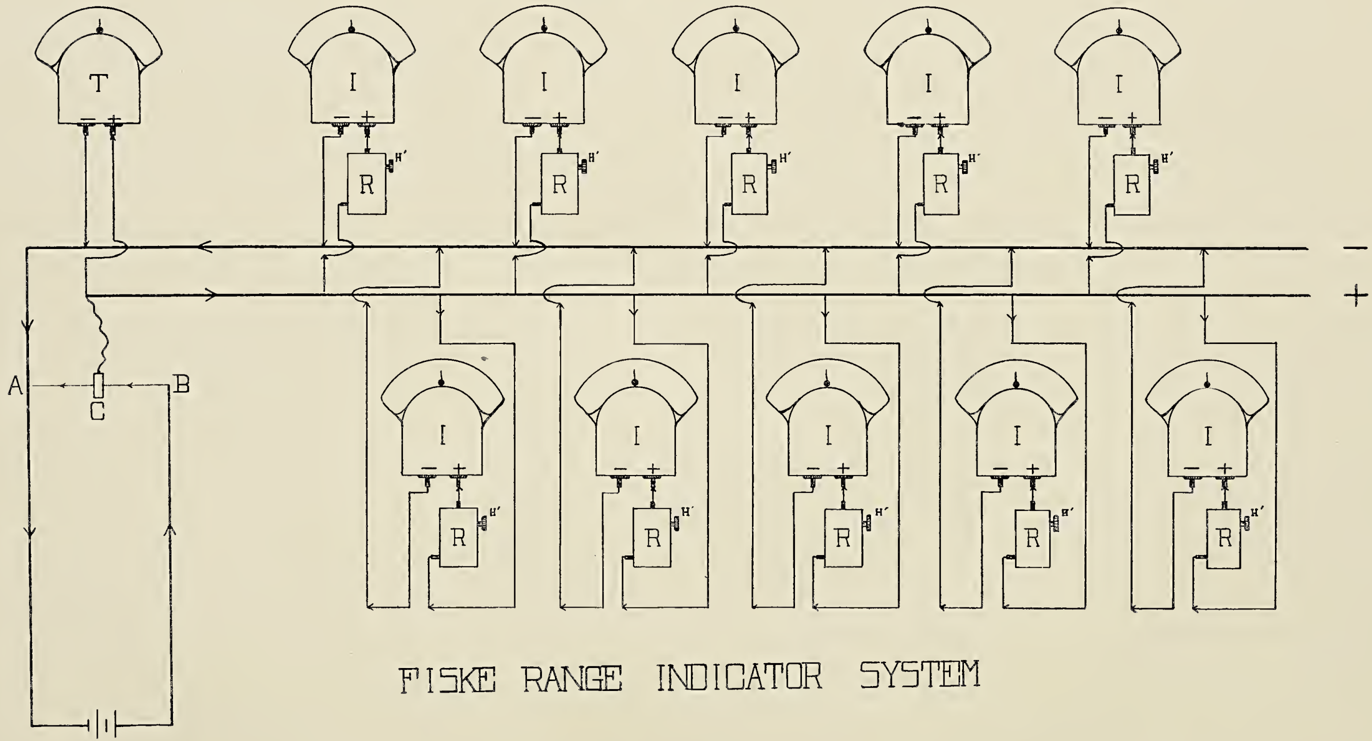


FIG. 17.



FISKE RANGE INDICATOR SYSTEM

Fig. 18.

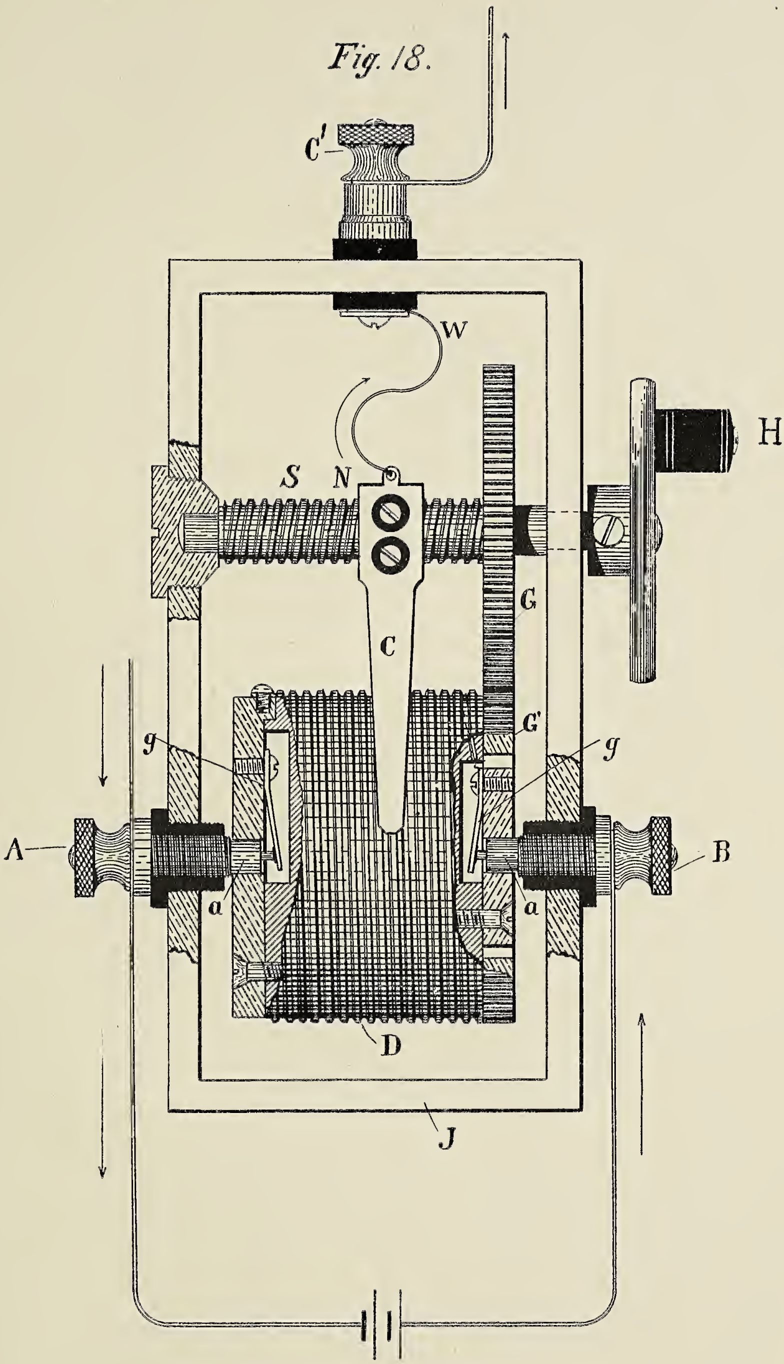


Fig. 19.

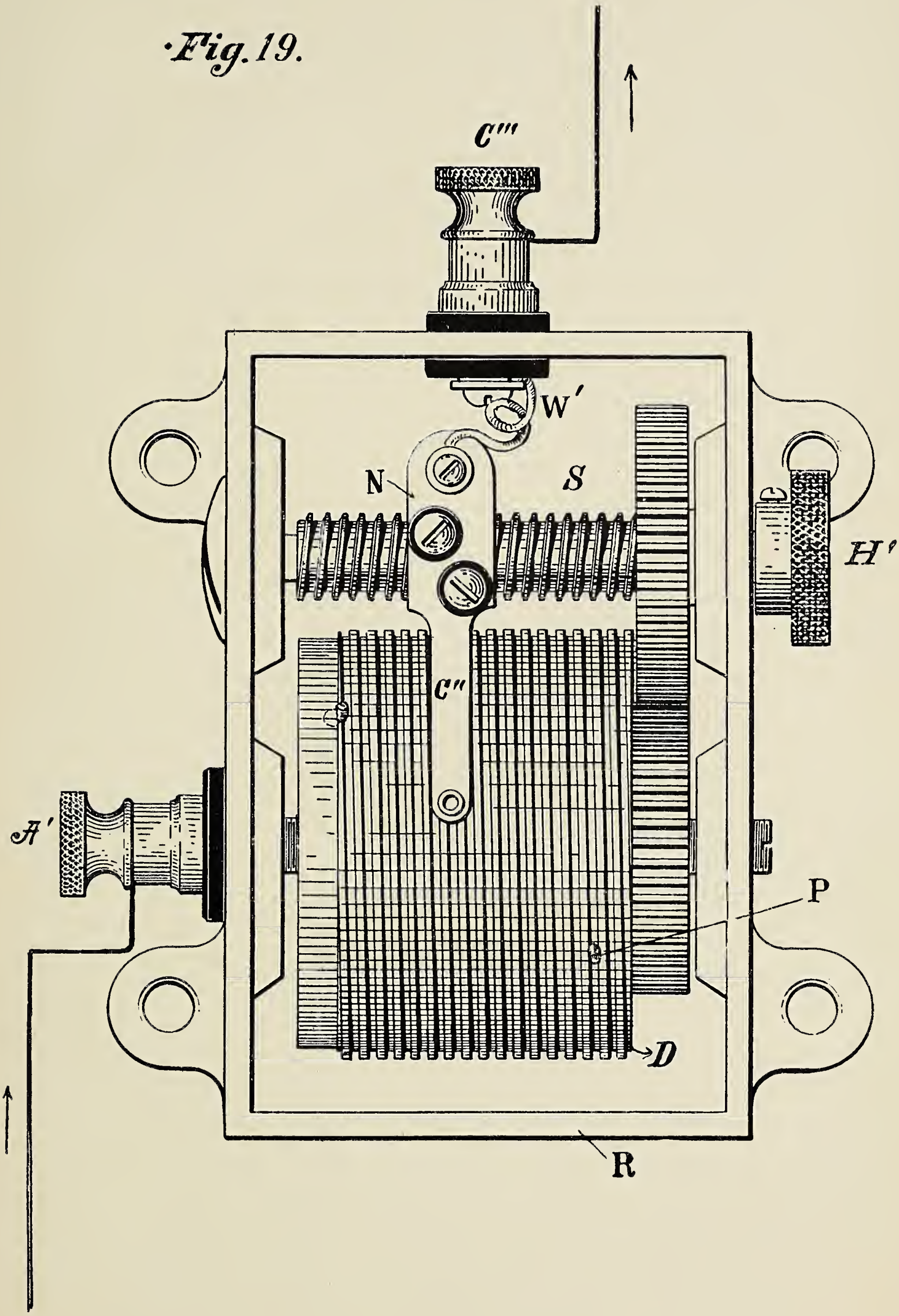
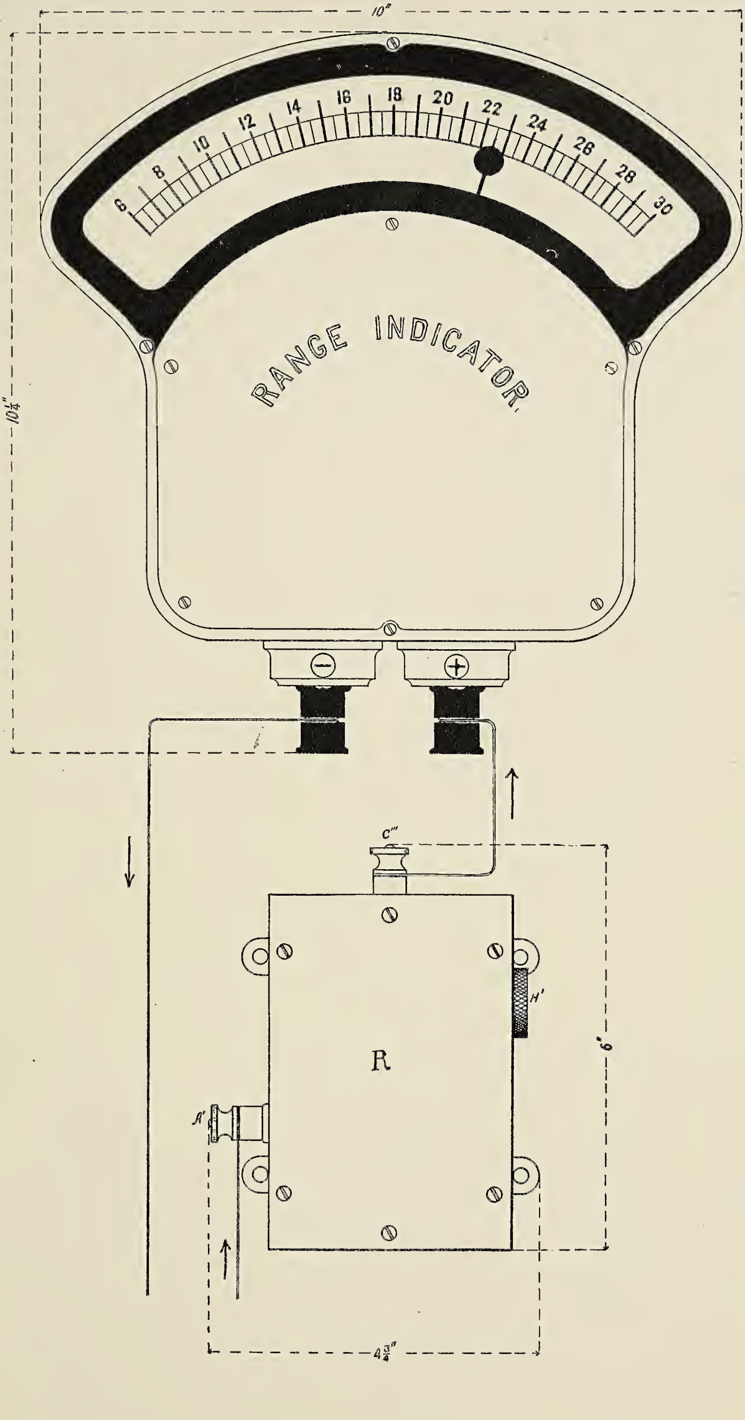


Fig. 20.



10"
6
8
10
12
14
16
18
20
22
24
26
28
30
RANGE INDICATOR.
10¼"
C'''
H'
R
A'
6"
4¾"